REMARKS/ARGUMENTS

In the Advisory Action, the Examiner again rejects claims 1-32 under 35 U.S.C. Section 102(b) as being clearly anticipated by "*Wide Area ATM Network Experiments Using Emulated Traffic Sources*" by Lee and claims 1-31 under 35 U.S.C. Section 103(a) as being unpatentable over U.S. 6,597,660 to Rueda et al. in view of "*Two-State MMP Modeling of ATM Superposed Traffic Streams Based on the Characterization of Correlated Interarrival Times*" to Kang. Applicant respectfully traverses the Examiner's rejections for at least the reasons stated below.

The Claimed Invention

The invention is generally directed to the modeling of packet traffic on an ATM network. This topic has been of intense interest since the earliest deployment of ATM equipment in telecommunications networks during the late 1980s. Reasons for the lack of accurate traffic models for ATM networks include not only the lack of real traffic data but also a general lack of understanding of the synergistic relationships between ATM switches, packet traffic, and traffic sources feeding into an ATM network.

An ATM network has some similarities to other types of packet communication networks (e.g., Ethernet, Internet Protocol (IP), etc.) in that the traffic is compartmentalized into discrete packets and aggregated (multiplexed) for transmission on high-capacity, high-bandwidth channels. The major differences between ATM and other packet communication protocols is that ATM uses a fixed packet length of 53 bytes whereas other packet communication protocols use a variable packet length. This uniform packet size is why ATM packets are referred to as "cells".

Furthermore, ATM is a connection-oriented protocol in which a dedicated connection is established between the sender and the receiver. Most other packet communication protocols are connectionless or "best effort", meaning that no dedicated connection is established between sender and receiver. In connectionless networks, the transmission equipment makes a "best effort" to get packets to their destination based on the packet header information. Lastly, ATM is the fastest of the packet communication protocols with possible transmission speeds in the multiple gigabits per second. These major differences contribute to the differences in the probabilistic distribution of ATM traffic packet interarrival times compared to other packet communication protocols.

Many of the references in the technical literature do not demonstrate a basic understanding of the way ATM switches operate. Basically, an ATM switch takes traffic from various sources (FTP, IP, Ethernet, TELNET, etc.) and encodes the information into the constant cell size format of the ATM protocol. I will illustrate with a simple example.

The operation of an ATM network can be explained using a simple highway analogy. Assume that an interstate highway has vehicles entering into it from various entrance ramps (ATM switches): (1) a busy downtown business district, (2) a rural agricultural area, and (3) a residential area. Let one assume that the traffic from sources (1), (2), and (3) enter the interstate at various speeds and that the vehicles (packets) are different lengths. One would expect that traffic entering the interstate from downtown would be a mix of personal and commercial vehicles. One would expect that traffic entering the interstate from the residential area would be

mostly personal vehicles. One would expect that traffic entering the interstate from the rural agricultural area would be a mostly slow-moving agricultural vehicles of fairly large size. If one were to extrapolate this highway analogy to an ATM network, the contents (drivers, passengers, and cargo) of all vehicles entering an interstate highway entrance ramp (ATM switch) would be removed and placed in another vehicle (for example, a Ford Mustang) which is identical to every other vehicle exiting the entrance ramp and entering the interstate highway (ATM network). Therefore, if a commercial passenger bus wishes to gain access to the interstate highway (ATM network), all of the passengers and all of the cargo would be removed from the bus and put in an appropriate number of Ford Mustangs. It is clear that the traffic from sources (1), (2), and (3) will have different probabilistic distributions because of the differences in source speeds and packet (vehicle) sizes. Accordingly, since the traffic on the interstate highway (ATM network) consists entirely of identical Ford Mustangs (ATM cells) which travel at very high speeds relative to the source traffic, the probabilistic distribution of the highway (ATM network) traffic will be different from the source traffic.

The ATM traffic simulation algorithm proposed by the Applicant is the first to be derived from observations and measurements of real ATM traffic. Interarrival times of ATM packets were measured by inserting packet "sniffers" at various points in the network and the interarrival times of ATM packets were modeled using probabilistic distributions. Most importantly, synthetic traffic was generated using the simulation algorithm and compared to actual traffic streams for

accuracy. In every case, the synthetic traffic generated by the algorithm was a very close match to the actual network traffic.

The present invention describes a mathematical model of the **data stream between ATM switches**. This data stream is composed of ATM packets (or cells) that are a uniform 53 bytes in length, per the ATM technical specification. An analysis of the traffic streams from two ATM networks showed that the interarrival times of ATM packets (cells) could be accurately modeled with a mixture model of log-normal and normal distributions. The normal distribution arises only when a receiving ATM switch buffer fills up and queues of delayed ATM packets form.

The Lee Reference

Lee teaches (pages 13, 20, 21, 25, 26, 28, 32) that some of the **source traffic coming into** an ATM network can be modeled with log-normal and normal distributions. For example, Lee discussed modeling the number of bytes transferred during an FTP session using a log-normal distribution. The average FTP packet size described by Lee is 50K bytes. Since an ATM packet is a uniform 53 bytes in length, Lee cannot possibly be applying a log-normal model to ATM network traffic. Furthermore, Lee is not even using **real** traffic, but rather **emulated** traffic based on various probabilistic distributions. In no instance does Lee state that he modeled the interarrival times for ATM traffic using log-normal variates. Specifically, Lee models only three network phenomena with log-normal variates:

1. The duration of TELNET sessions (page 20),
2. The bytes transferred during an FTP session (page 25),

3. The frame size of MPEG video (page 29).

Lee teaches on page 20 that Telnet session durations (the time between login and logout) can be modeled with a log-normal distribution. Here again, Lee's application is to a TELNET user session rather than ATM traffic flows. Furthermore, Lee assumes a 1 byte packet size for TELNET transmissions.

Lee neglects to consider that although various traffic sources may have different probabilistic distributions and packet sizes, an ATM switch will encapsulate that traffic into the uniform 53 byte cell size specified by the ATM standard. Regardless of the probabilistic distribution of the source traffic, the aggregate ATM traffic streams between ATM switches will have a different probabilistic distribution due to the high speed characteristics of ATM switches and the uniform cell size of ATM packets.

Lee provides no indication that any traffic measurements were taken from actual ATM network traffic nor does he provide any comparisons of emulated traffic to actual traffic.

<u>Rueda et al.</u>

Rueda et al. teaches that ATM network can be simulated with a general algorithm applicable to all types of packet networks. Rueda et al.'s invention describes a self-similar model for ATM network traffic. The mean and variance modeling referred to by Rueda et al. describes the parameters of this self-similar model. While a self-similar model is applicable to some packet networks (e.g. Ethernet, Internet Protocol (IP)), it has been shown analytically and mathematically that a self-similar model is not applicable to ATM network traffic. A self-similar model is based on normal probabilistic variates. Basically, the uniform packet (cell) size and bursty nature of ATM traffic precludes the application of a self-similar model. ***In no instance is it explicitly stated or implied by Rueda et al. that ATM traffic can be modeled with log-***

normal variates. While it has been shown that the **delayed** traffic in an ATM network can be characterized with a pseudo self-similar model, this fact is not expressed or implied in the teachings of Rueda et al. Lastly, Rueda et al. provides no comparison of the traffic generated by their algorithm to real ATM network traffic, or any other packet network traffic.

The Kang Reference

Kang teaches that the interarrival times of ATM network traffic can be modeled by a Markov Modulated Poisson Process (MMPP). It has been shown (by the Applicant) that the low degree of correlation between interarrival times and the shape of the interarrival distribution (log-normal as opposed to exponential) means that the Markovian based models, which are based on exponential variates, are not accurate models for ATM network data. ***In no instance does Kang discuss the modeling of ATM packet traffic using log-normal variates.*** Indeed, doing so would undermine the basic premise of his paper. In other words, ATM traffic cannot be modeled by a MMPP, which is characterized by an exponential probabilistic distribution, and also have a log-normal distribution. This is analogous to saying that an apple can be modeled by a watermelon. Most importantly, the term "log-normal" does not appear in the paper. Kang presents a purely mathematical analysis with no collection and analysis of real ATM network traffic data. He offers no methodology for evaluating his model in a real-world context nor does he provide any comparisons of model generated traffic to actual network traffic.

Discussion of Patent Examiner's Final and Advisory Actions

1. The Examiner states (page 2 of Final Action) "Both applicant's specification, and the Lee article recognize that real-world inter-arrival times of packets in ATM networks can have a lognormal probabilistic distribution, and that delayed packets follow a normal distribution. (See Lee pages 20, 25, 29, Tab. 4.1)

Applicant's Response: The Applicant has not been able to locate a discussion in Lee's paper concerning the normal distribution of delayed packets on an ATM network, on the pages specified by the Examiner, or anywhere in Lee's paper. Furthermore, and most importantly, the pages cited by the Examiner concern the application of lognormal modeling to the duration of TELNET sessions, the number of bytes transferred during an FTP session, and the sizes of MPEG video frames. In no instance is there a discussion of the modeling of ATM packet interarrival times with log-normal variates. Lee is concerned with the modeling (emulation) of ATM **source traffic** rather than the traffic transported on the ATM network by ATM switches (Lee page 13 and Abstract). Lee only discusses packet interarrival times in one instance (page 21): he uses pareto variates to model TELNET packet interarrival times. None of the figures (3.5, 3.6, 3.8, and 3.9) concern packet interarrival times.

2. The Examiner states (page 4 of Final Action): "Lee teaches techniques for the modeling, simulation, and emulation of ATM network traffic and packet **inter-arrival times** between sessions of packets (first, second, etc.)."

Applicant's Response: The examiner implies that the interarrival times of **sessions** of packets is identical or closely related to the interarrival times of **individual** packets. The interarrival times between **sessions of packets** (Lee's teaching) are in no way related to the **interarrival times of individual packets** (Applicant's invention). This is analogous to saying that the interarrival times of individual vehicles exiting an interstate highway is the same as a large convoy of vehicles exiting the same highway.

3. The Examiner states (page 4 of Final Action): "Lee further discloses modeling (generating) packet arrival times using log-normal number distribution and normal number distribution."

Applicant's Response: Lee models the interarrivals of TELNET and FTP sessions using a log-normal distribution. In the one instance where Lee models the interarrival time of ATM packets, he uses a **pareto** distribution. This is analogous to modeling the interarrival time **between** telephone calls rather than the interarrival time between the packet traffic generated **by** the telephone calls.

4. The Examiner states (page 5 of Final Action): "Lee further discloses modeling the mean and variance of log-normal and normal distribution packet arrival times. (see pages 16, 19, 20, 24, and Figs. 3.1, 3.2)"

Applicant's Response: Again, Lee models the interarrivals of sessions of TELNET and FTP sessions using a log-normal distribution. In the one instance where Lee models the interarrival time of ATM packets, he uses a **pareto** distribution.

5. The Examiner states (page 6 of Final Action): "Reuda implies, but does not explicitly teach characterizing and modeling (generating) the packet inter-arrival times using log-normal and normal distribution"

Applicant's Response: Reuda explicitly teaches modeling ATM packet interarrival times with a self-similar model, which is characterized by a normal distribution. The use of self-similar models for ATM packet traffic was widely accepted, but never proven during the 1990's. Reuda's reference literature list contains many papers that propose a self-similar (or fractal) model for packet network traffic. When it was proven that self-similar (or fractal) based models could accurately characterize traffic on **some** packet networks (e.g. Ethernet), some researchers, including Reuda, extrapolated that these self-similar (or fractal) models could be applied to ATM networks. However, ATM's fine-grained packet structure and lognormal distribution of interarrival times also preclude the use of the popular self-similar, or fractal models for ATM traffic.

The Applicant's analytical results revealed that ATM data traffic is bimodal, and can be accurately modeled with the mixture model

$$F(x) = \Psi \cdot \Lambda(\mu_1, \sigma^2_1) + (1 - \Psi) \cdot N(\mu_2, \sigma^2_2)$$

where $F(x)$ is the probabilistic distribution of the traffic, Ψ is the mixture parameter, Λ is a lognormal distribution which describes the vast majority of the traffic, N is a normal distribution which describes the remainder of the traffic (which is delayed due to the switch buffer being full), and μ and σ^2 are the mean and variance respectively, of the two distributions. The mixture parameter is dependent on (1) the speed at which traffic enters and leaves the switch, (2) the *priority* of the traffic, and (3) the size of the switch input buffers. As the transmission speed and/or buffer size increases, the parameter Ψ tends to 1 and the traffic distribution tends to total lognormality. ATM networks are designed to multiplex and transport voice, video, and data. Because video and voice traffic has higher sensitivity to delay, they are assigned a higher priority than data with regard to admission to a switch. For example, if a voice packet, a video packet, and a data packet arrive at a switch simultaneously, the video packet would be admitted to the switch input buffer first, then the voice packet, and then the data packet.

For video and voice, the term Ψ is very close to or equal to one and the model reduces to

$$F(x)=\Lambda(\mu_1,\sigma^2_1).$$

Although models for ATM traffic have been proposed in the literature since the late 1980's, no known previous study of ATM network traffic has provided a model of voice, video, and data which is consistent with the underlying mechanisms which shape traffic behavior, and which is based on observations of real data. The ATM modeling community has been at a severe disadvantage due to the scarcity of data from real ATM networks. Many researchers resorted to

using traffic data from Ethernet networks, since, Ethernet and ATM are both packet communication technologies and share some similarities.

6. The Examiner states (page 6 of Final Action) "Kang teaches characterizing, simulation, and modeling (generating) of ATM network packet inter-arrival times using log-normal (logarithmic) and normal distribution"

Applicant's Response: The terms "lognormal" and "normal" do not appear in the text of Kang's paper. Kang does use the term "logarithmic scale". Here, Kang is referring to a graph plotted with a logarithmic scale for a **hyperexponential** distribution (Figure 1, page 1423). Kang's model is based on a Markov Modulated Poisson Process which, in turn, is based on an exponential, or hyperexponential distribution. **Any mathematician will verify that a statistical population cannot be based on both exponential and lognormal distributions because they are mutually exclusive**. Indeed, the use of lognormal or normal distributions in Kang's model would undermine and invalidate the entire premise of the paper.

Furthermore, the Applicant has shown that the low degree of correlation between interarrival times and the shape of the interarrival distribution (lognormal as opposed to exponential) means that the Markovian based models such as the Markov Modulated Poisson Process (MMPP) are not good candidates for characterizing ATM packet traffic. Markovian based models all have some form of hyperexponential interarrival density function. The Markovian based models have, however, been shown to be good models for data traffic on Ethernet networks.

7. The Examiner states (page 7 of Final Action): "Per dependent claims 2-7, 9-15, 17-25, 27-31: This group of claims is drawn to limitations that include characterizing and modeling (generating) the packet inter-arrival times using log-normal and normal distribution **which is disclosed by Kang** as cited above."

Applicant's Response: See Applicant's response in item 6 above.

<u>Conclusion</u>

Prior to the Applicant's invention, there were two schools of thought pertaining to the modeling of ATM network traffic: (1) ATM traffic could be modeled using self-similar (or fractal) models and (2) ATM traffic could be modeled using Markovian based models that had been used for over a century to model voice telephone traffic. Because of the dearth of traffic data from real ATM networks, researchers in this area have relied on simulated data and data from Ethernet networks. Ethernet and ATM are both packet technologies and share some similarities. There are, however, important differences between the two technologies which largely preclude the use of Ethernet traffic data in studies of ATM network traffic behavior. The Applicant proposed a model for ATM data traffic based on analysis of traffic traces from two real ATM networks. That analysis revealed that the interarrival time distribution for data traffic is bimodal, in a similar fashion to Ethernet, but is a mostly lognormal mixture distribution with a very small self-similar or pseudo self-similar portion in the right tail.

Based upon the foregoing, Applicants believe that all pending claims are in condition for allowance and such disposition is respectfully requested. In the event that a telephone

conversation would further prosecution and/or expedite allowance, the Examiner is invited to contact the undersigned.

Respectfully submitted,

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